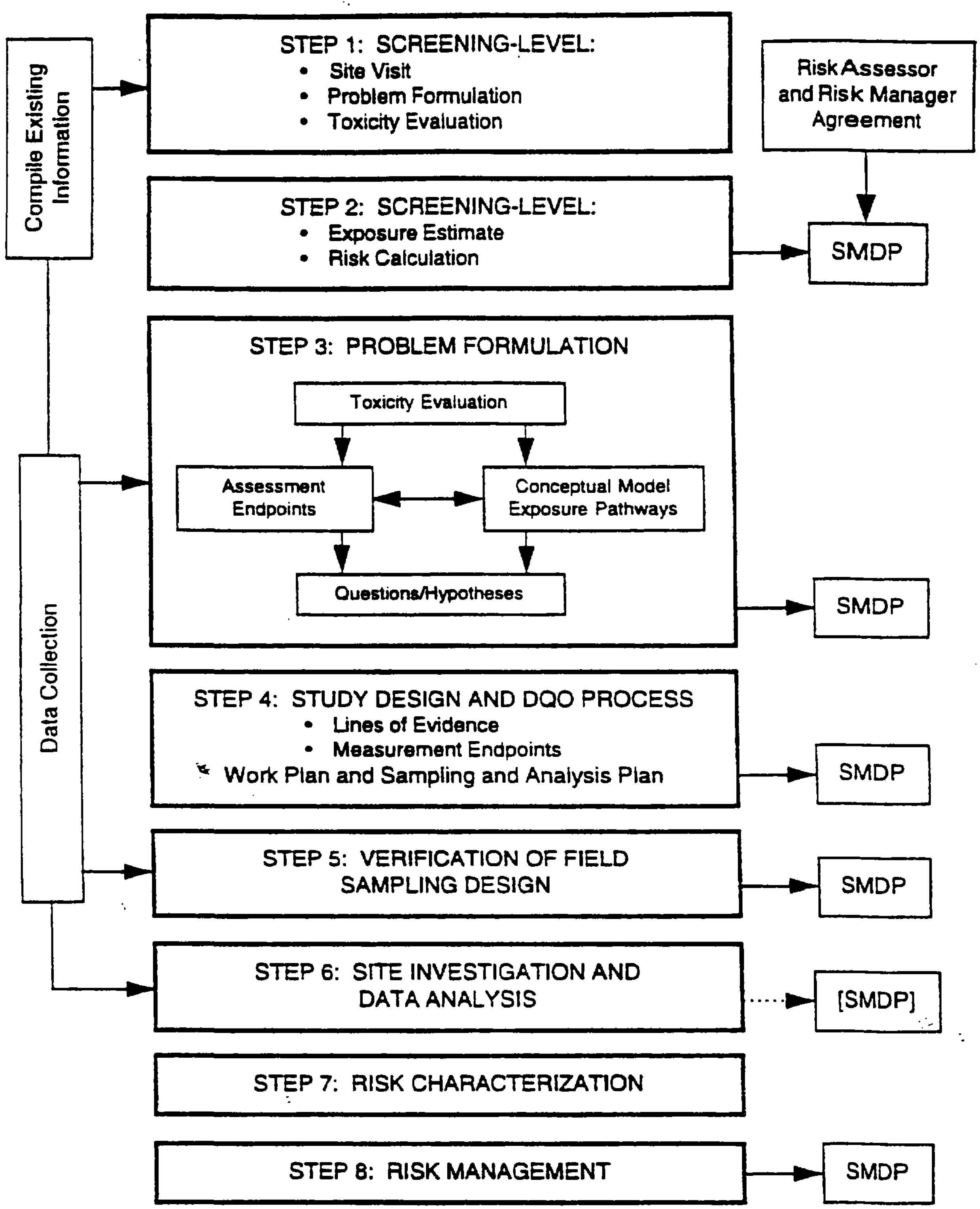
Ecological Risk Assessment For the Coal-Tar Contaminated Sediments And Surface Waters Off of the Ashland Lakefront Property In Ashland Harbor

Prepared By SEH For WDNR
October 1998

Handouts Prepared For August 10, 1999 WDNR/EPA Meeting

EXHIBIT I-2
Eight-step Ecological Risk Assessment Process for Superfund



1.

Ecological Risk Assessment For the Contaminated Harbor Sediments Adjacent to the Ashland Lakefront Property (Kreher Park)

Introduction

The Wisconsin Department of Natural Resources (WDNR) through Short Elliott Hendrickson Inc. (SEH) recently completed an Ecological Risk Assessment (ERA) for the contaminated sediments in an area that comprises approximately 10 acres of the harbor that extends from 300 to 700 feet off shore from Kreher Park in water less than 10 feet deep and between jetties to the east and west. Previous investigations have identified the contaminants of concern as volatile organic compounds (VOCs) and polycyclic aromatic compounds (PAHs). The contaminants are associated with black tarry materials and appear to be most concentrated at the interface of a wood chip layer (that covers a large part of the area to an average depth of 9 inches) and the underlying fine sands and silty sands. The contamination was generally present in the upper 10 feet of the sandy sediments and decreased with depth till underlying, cohesive parent materials were reached.

Contaminant Sources

Given the large area of bottom sediments contaminated and the visible black, tarry characteristics associated with the contamination, there is only a limited number of possible contributing sources to this type of contamination. A major contributing source was likely releases of coal tar wastes from the Manufactured Gas Plant (MGP) that operated up on the bluff from the late 1800's until 1947. MGPs generated gas for residential heating and lighting from heating coal in retorts. Coal tars were a by-product of the gas generation process. Disposal of waste products were largely unregulated during the period of active coal gas production. Coal tars from the Ashland MGP have been identified in the ravine off of the bluff, the deep groundwater aquifer, and in the filled area of the Ashland Lakefront property.

As more and more MGP sites are being investigated around the state, coal tar wastes are being found in the bottom sediments of surface waters associated with a large number of the sites. Even 40 to 50 years after the MGPs have ceased operating, the coal tar wastes have remained at or near the sediment surface and at depth to impact aquatic resources on a continuing and long term basis. Organic and metal compounds from MGP wastes are toxic to bottom dwelling organisms and can be released from bottom sediments by various means to the overlying water in dissolved forms, associated with suspended particulates, or as separate oils, all of which may be available and toxic to fish and other aquatic organisms. Coal tar wastes may contain thousands of organic compounds of which there is the ability to routinely analyze and identify only a portion. Many of the unidentified may be as equally toxic as those that can be identified.

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Ecological Risk Assessment

The purpose of the Ecological Risk Assessment was to estimate the current and future risks and impacts from contaminants of concern present in the surface waters and sediments of the site to plants, fish, and other aquatic organisms that would normally occupy the site habitats and birds and wildlife that may use utilize the habitats as part of their foraging base. A previous assessment looked at the risks to human health from exposure to the site contaminants.

The Ecological Risk Assessment used a weight-of -evidence approach to link the observed and measured sediment and water contamination found at the site to actual and predicted impacts to fish and other aquatic organisms that may use the harbor area off of the Lakefront Property. The weight-of-evidence approach depends on using multiple methods of associating the contaminant levels to effects to different organisms who are exposed to the contaminants by different exposure routes.

The weight-of-evidence of impacts was built on the following: 1) Representative fish, water column, and benthic test organisms were exposed to sediments and water were collected from the contaminated site and a clean site in a series of laboratory toxicity tests, 2) samples of the organisms inhabiting the bottom substrates of the site were collected to look at the number and diversity of species present and compared with those from uncontaminated sites, 3) review of the results of studies conducted on other sites with the same groups and levels of the contaminants of concern and methods of exposure to organisms, and 4) use of published guidelines or criteria that relate sediment and water concentrations of the contaminants to effects to fish and other aquatic organisms and a comparison of these guideline/criteria concentrations to measured concentrations found at the site.

Integration of the above study components leads the WDNR to conclude that the ecological *risks associated with the contaminated sediments off* of the Ashland Lakefront Property are likely to be high for the present and for the long term. Given the bottom characteristics, PAHs will not attenuate or naturally breakdown over time as evidenced by their toxicity 50 to 60 years after being released to the harbor. Risks and impacts to the insects, worms, crustacea, and other species that inhabit the bottom substrates for all or some portion of their life cycles and for water column organisms such as immature fish, are expected to be highest. The bottom dwelling community *serves as part of the food chain* that supports higher trophic levels or larger consumers such as fish. It is likely the bottom dwelling community is limited as a food source at the site, and those organisms that can survive may accumulate PAH contaminants and pass them onto higher level consumers. Immature fish impacted by the site contaminants also means a possible loss of a food base for higher level consumers and loss of fish stock to the bay and the lake. The health of larger fish utilizing the area may also be impaired.

Some of the PAH contaminants at the site have the unique characteristic of having their toxicity to bottom dwelling and water column organisms such as fish enhanced or increased by sunlight that can penetrate through the water to the bottom substrates and activates the PAHs in the process. In all the above cases, the direct evidence indicates that the shallow

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near-shore habitat off the Ashland Lakefront property is impaired and not supporting a healthy, balanced community of aquatic organisms. These impacts may have secondary impacts to higher trophic level organisms such as birds and wildlife that use the habitat as a foraging base.

Feasibility Study For Sediment Remediation

Based on the results of the Ecological Risk Assessment, the WDNR will be undertaking a feasibility study to evaluate remedial alternatives for the contaminated sediments of the site. The overall objective for remediating the contaminated sediments off of the Lakefront property is to protect the unique resources of the Chequamegon Bay and Lake Superior Ecosystems. All necessary means will be taken to protect these resources from any degree of degradation or impairment.

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Summary of Ecological Risk Assessment - Weight of Eviden

Benthic Community

Adsorbed Chemical PAH and VOC concentrations in sediments

Exceedance of several different sediment effects benchmarks for PAHs and VOCs concentrations in sediments

Impacted Benthic Community per Spring 1998 Survey

Toxicity Study results indicate PAH contaminated sediments are toxic to benthic organisms

UV Exposure results indicate PAH contaminated sediments are toxic to benthic organisms

Degradation of lower order foodchain microorganism populations based on microbial enumeration bioassays

Aquatic Community

Adsorbed Chemical PAH and VOC concentrations in sediments

Exceedance of several different sediment effects benchmarks for PAHs and VOCs concentrations in sediments

PAH concentrations in sediments at levels comparable to those associated with tumors in fish at other sites

Exceedance of acute and chronic criteria for water quality during wave action

Reports of sheen and odors in surface waters above contaminated sediments

Potential for release of more heavily contaminated deeper sediments due to natural or anthropogenic disturbances.

Toxicity Study results indicate PAH contaminated sediments are toxic to fish fry

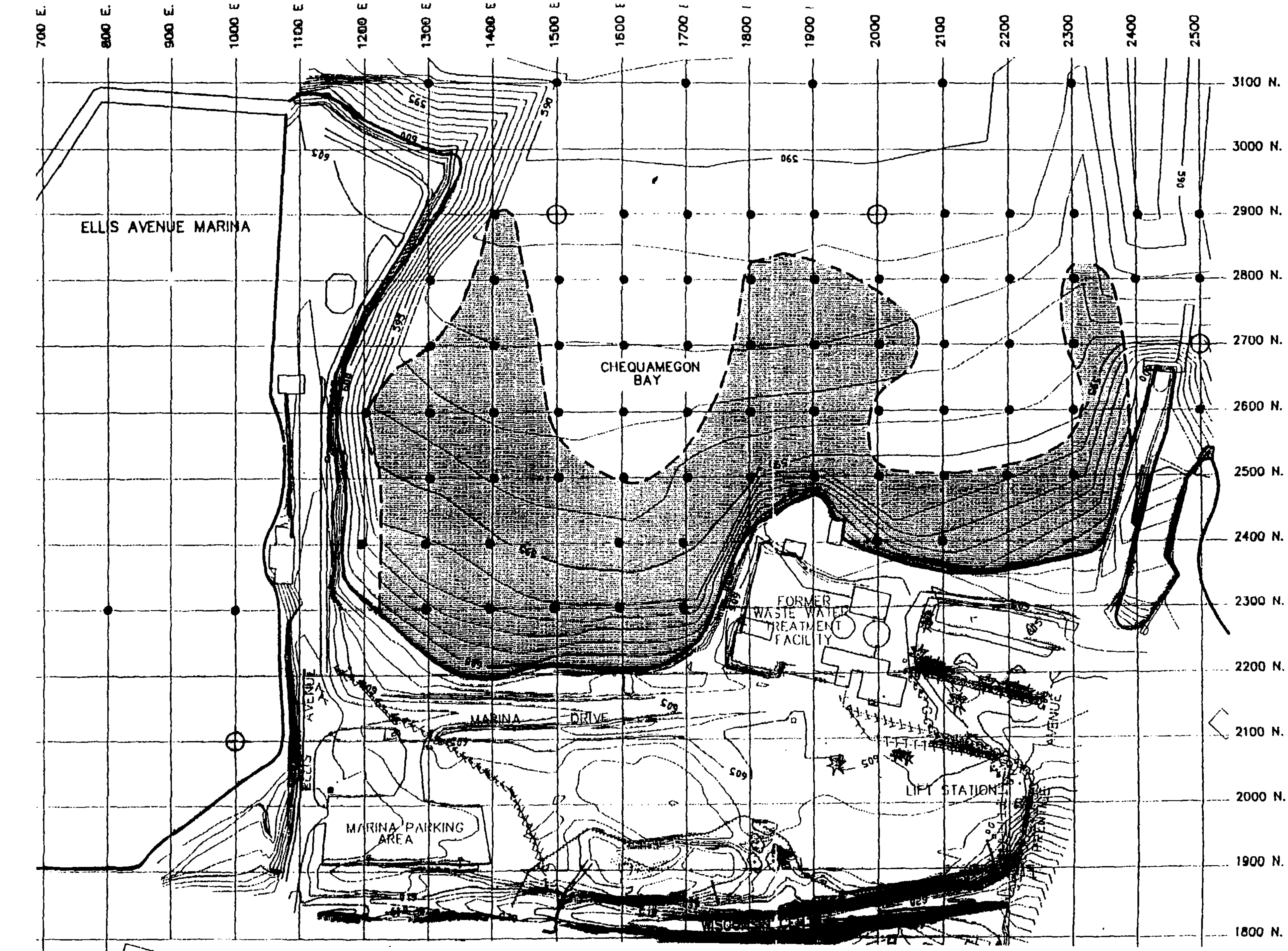
UV Exposure results indicate PAH contaminated sediments are toxic to fish fry and daphnia magna

Terrestial Community

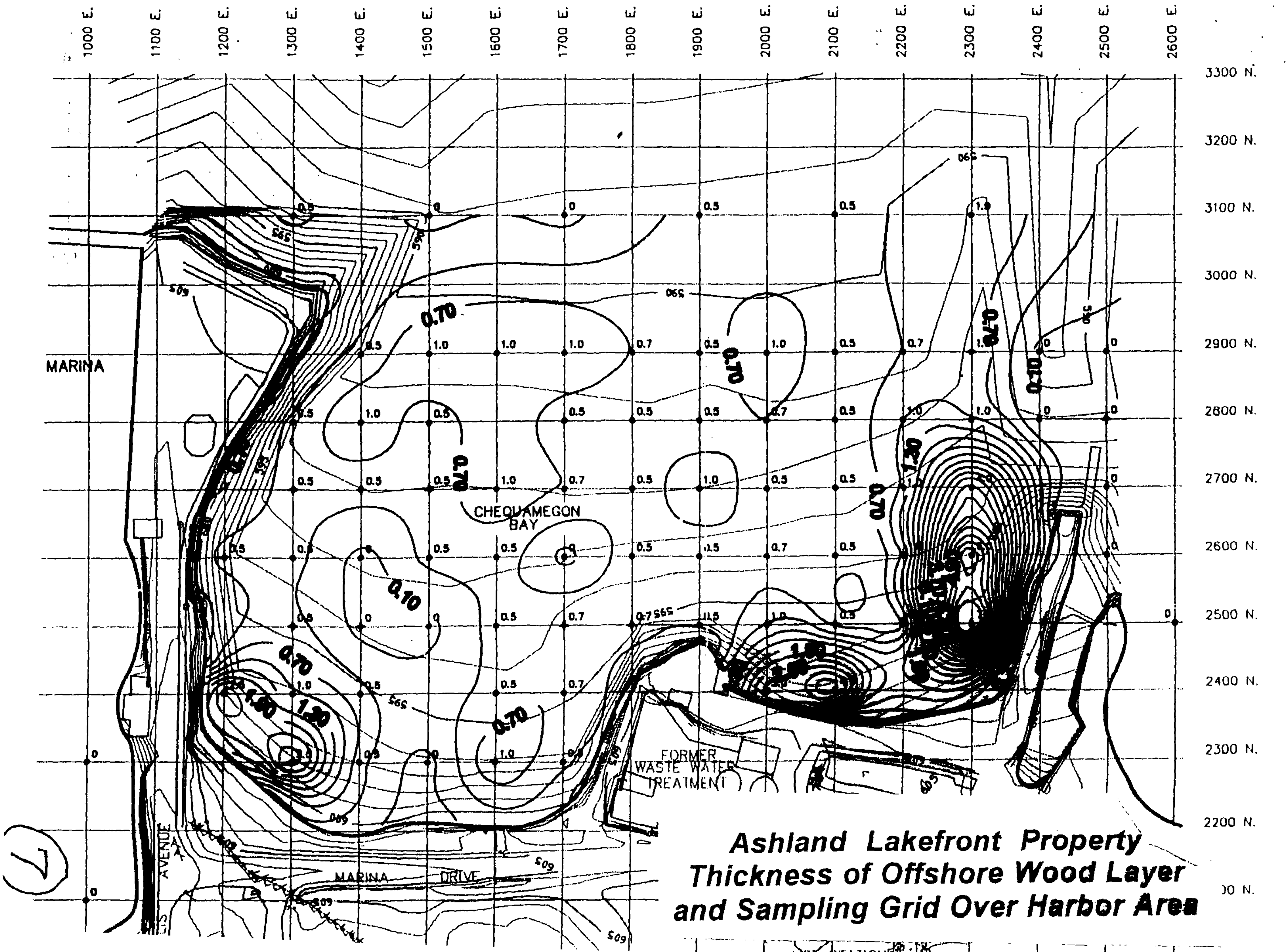
HHRA indicated risk of cancer to humans from exposure to sediments or contaminated water

Lower order food chain impacted - decreases quantity and quality of fish and other food sources

Potential for uptake of PAH contaminants by terrestial organisms feeding on lower order aquatic or benthic organisms that may bioaccumulated contaminants.



Ashland Lakefront Property - Sampling Grid Over Contaminated Harbor Area



Ashland Lakefront Property
Thickness of Offshore Wood Layer
and Sampling Grid Over Harbor Area

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FIELD COLLECTIONS PERFORMED AT THE ASHLAND HARBOR SEDIMENT SITE

A. Sediment Chemistries

- *In 1996, a sampling grid was established at 100 foot nodes over the 10 acre site.*

- *Sediment cores were obtained at 80 locations to depths up to 24 feet below the lake bottom and analyzed for PAHs, VOCs, and other contaminants.*

- *Additional sediment cores were obtained during the winter of 1998 for chemical analysis as part of the scoping studies for the Ecological Risk Assessment.*

B. Surface Water Samples

- *Special event sampling during period of high wind and wave action to determine amount of disturbance of contaminated bottom sediments and amounts of contaminants introduced to the water column. (Laboratory sediment settling and PAH dispersion studies also conducted).*

C. Biological Studies

Benthic Macroinvertebrates

- *Early 1998, preliminary sampling done of benthic community as part of scoping studies for Ecological Risk Assessment*

- *1998, benthic macroinvertebrate communities sampled at four type of habitats based on scoping work -*
  Reference Sand, Contaminanted Sand
  Reference Wood, Contaminanted Wood

- *Additional Plans were to collect benthic invertebrates for tissue analysis for PAHs but sufficient biomass could not be obtained.*

Fish Studies

- *Two rounds of fish collections were done in the contaminated harbor area by electroshocking and netting to obtain representative species for tissue analysis of PAHs and other studies. Analytical results are not available.*

TOXICITY TESTING PERFORMED ON THE ASHLAND HARBOR SEDIMENTS

Sample Sites

Reference Wood (RW)
Contaminated Wood (CW)
Reference Sand (RS)
Contaminated Wood (CW)

Sample sites selected based on results of initial sediment sampling on grid over area

A. Solid Phase Sediment Toxicity Testing

Tests were acute exposures of 10-days duration. Endpoints were survival and weight.

Test Organisms

1. *Hyalella azteca - amphipod*
2. *Chironomus tentans - midge larvae*
3. *Lumbriculus variegatus - oligochaete*

B. Sediment Elutriate Tests

Elutriate was prepared in a 1:4 volume ratio of sediment to test water, supernatant centrifuged.

Test Organisms (Initially in undiluted, 100% elutriate)

1. *Daphnia magna - 48 hr exposure, survival.*
2. *Pimephales promelas (fathead minnow) - 7 day exposure, survival and weight.*

Due to the high moralities in the undiluted elutriates from the CS and CW sites, a 7-day test with a series of elutriate dilutions (50, 25, 12.5, and 6.25 %) was performed with P. promelas.

C. Ultraviolet (UV) Light Toxicity Enhancement Tests

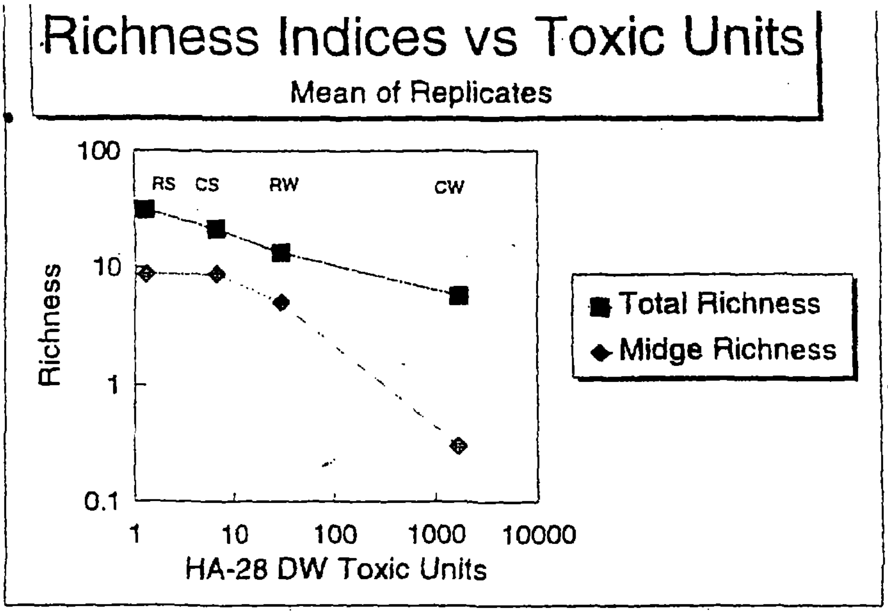
Testing involved UV exposures for 2 - 4 hrs from above setups

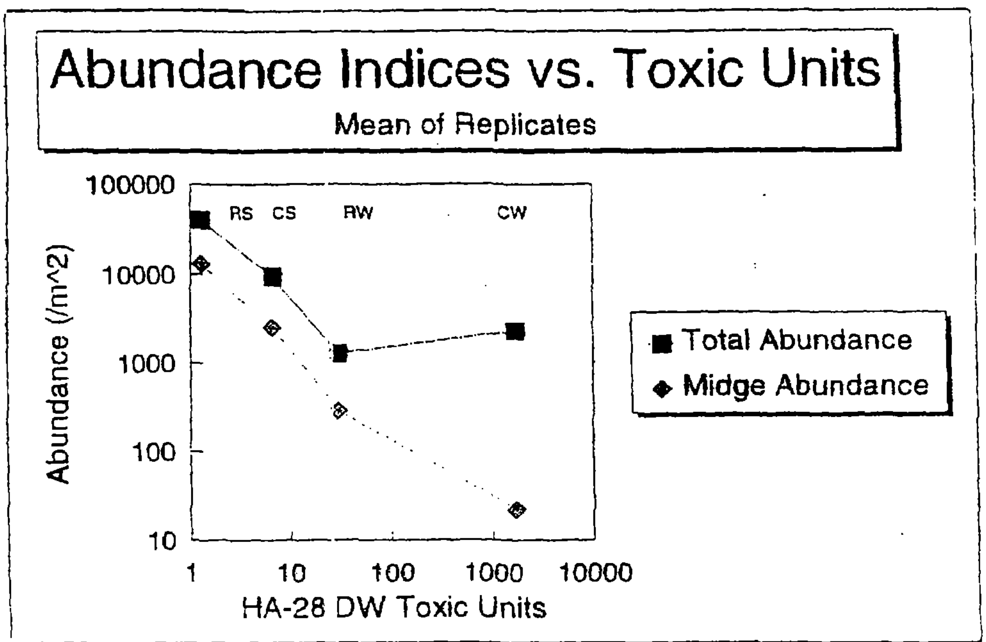
Test Organisms

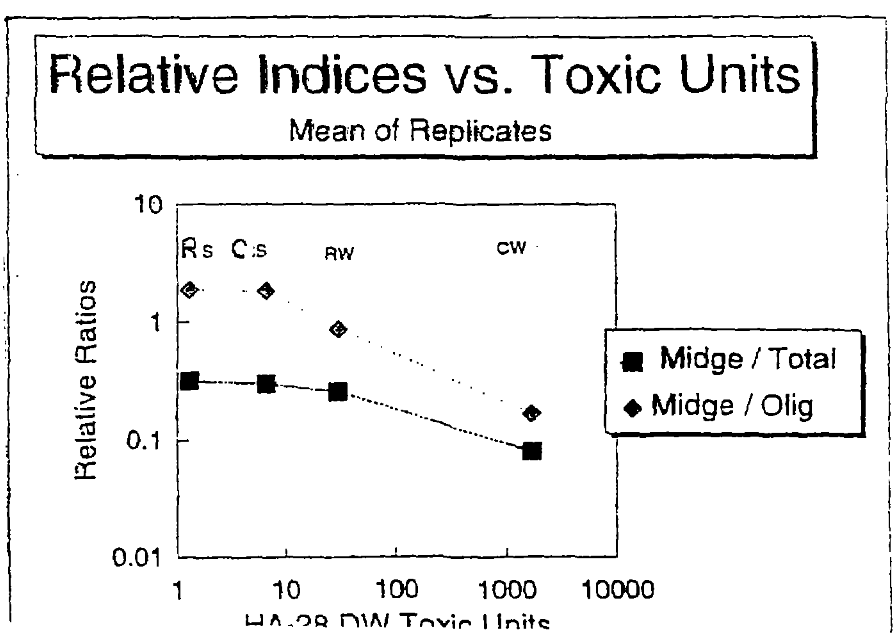
1. *L. variegatus*
2. *D. magna*
3. *P. promelas*

Benthic Macroinvertebrate Studies

Ashland Lakefront Property Harbor Area







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The shaded indices in the following table represent the D & M interpretation of "probable impacts" due to the decrease in the index when the reference site results are compared to the study site results.

Indices	Reference Wood		Contaminated Wood		Reference Sand		Contaminated Sand	
	Mean	std. dev.	Mean	std dev.	Mean	std.dev.	Mean	std. dev.
Total Taxa Richness	***13.2***	***5.4***	***5.7***	***3.5***	**30.8**	**5.8**	**21.2**	**2.6**
Midge Taxa Richness	5.2	2.8	0.3	0.5	**13.2**	**3.1**	**8.8**	**1.2**
Total Abundance (m2)	1285	776	2282	3410	40,498	13,542	9459	4542
Midge Abundance (m2)	**287**	**228**	**21.5**	**36**	13,169	6342	2541	728
Oligochaete Abundance (m2)	366	330	1478	1888	8146	3442	1651	836
Relative Midge Abundance	0.26	.18	0.08	0.20	0.32	0.12	0.30	0.13
Midge / Oligochaete Ratio	0.86	0.80	0.17	0.41	1.86	1.13	1.80	0.81

Shaded indices represent D & M interpretation of "probable impacts.
Indices in bold and larger font appear to meet the criteria of no overlap or single point overlap in ranges but were not included by D & M as "probable impacts".
The index in italic and in bold and larger font represents where the range as determined by the standard deviation did not overlap between the RW and CW sites and therefore the index is interpreted as showing probable impacts.

Based on the above D & M qualitative methods, it also appears that the a.) midge abundance (contaminated wood compared to reference wood with no overlap) , b.) total taxa richness (contaminated sand compared to reference sand with one point of overlap), and c.) midge taxa richness (contaminated sand compared to reference sand with one point of overlap based on a revision to the SEH ERA Appendix A calculation tables) also could be considered "probable impacts". It is uncertain why D & M omitted these three indices (or at least the one index with no overlap) for the sites along with the other four they have identified. If the criteria was the range of the standard deviation from mean rather than maximum and minimum values, the total taxa richness index for contaminated wood compared to reference wood would also show probable impacts. The above represents four additional indices to make a total of eight that show that there are impacts between the contaminated sites and the reference sites based on qualitative comparisons.

D & M states that **"statistical evaluations afforded by the existing data are limited because of small sample sizes and large resulting variances."** (p. 17)

We do not agree with this. Given the background discussion on statistics and the need to apply the correct interpretive terminology to the results of statistical evaluations as reflected in the D & M rebuttal comment 2, it is not understandable how statistical evaluations are limited based on the available data (see comment 42 below).

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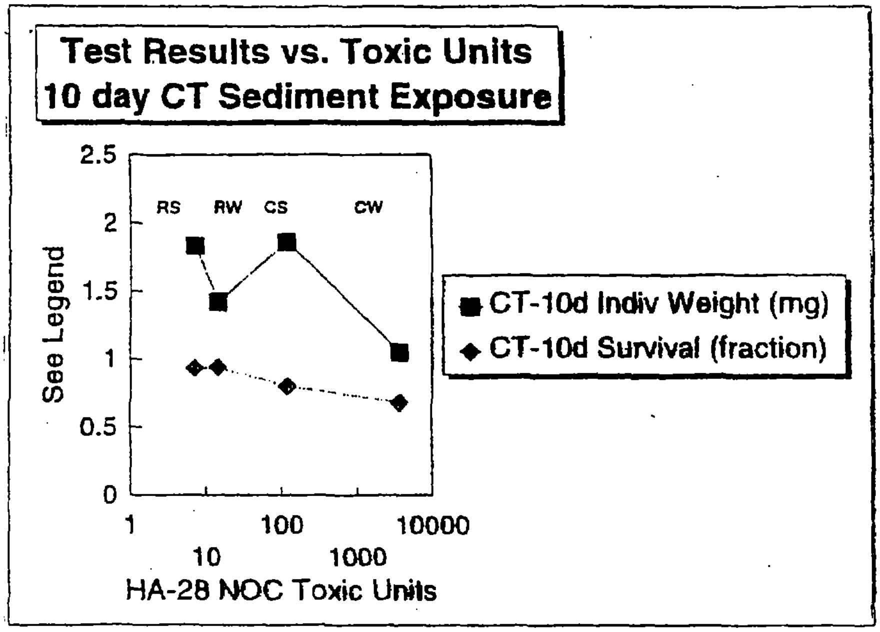
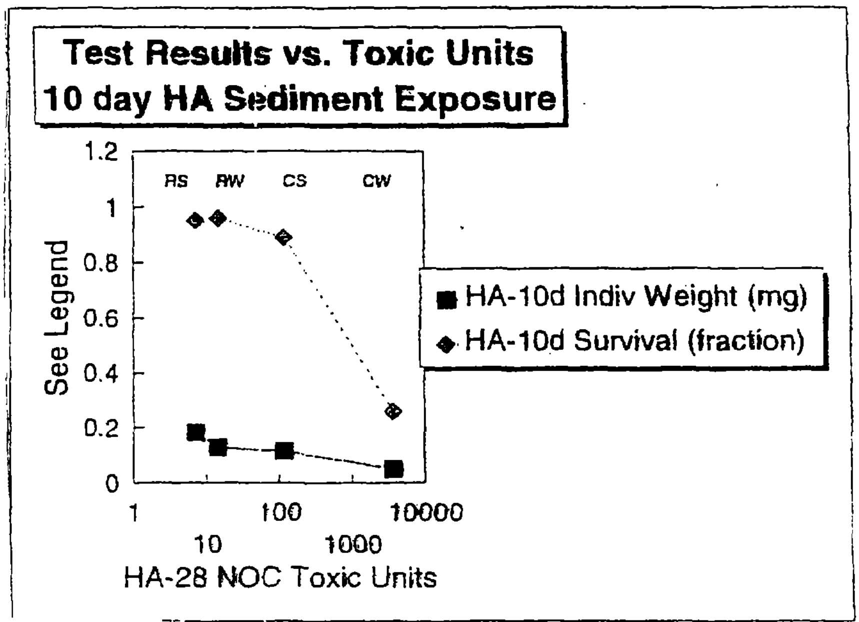
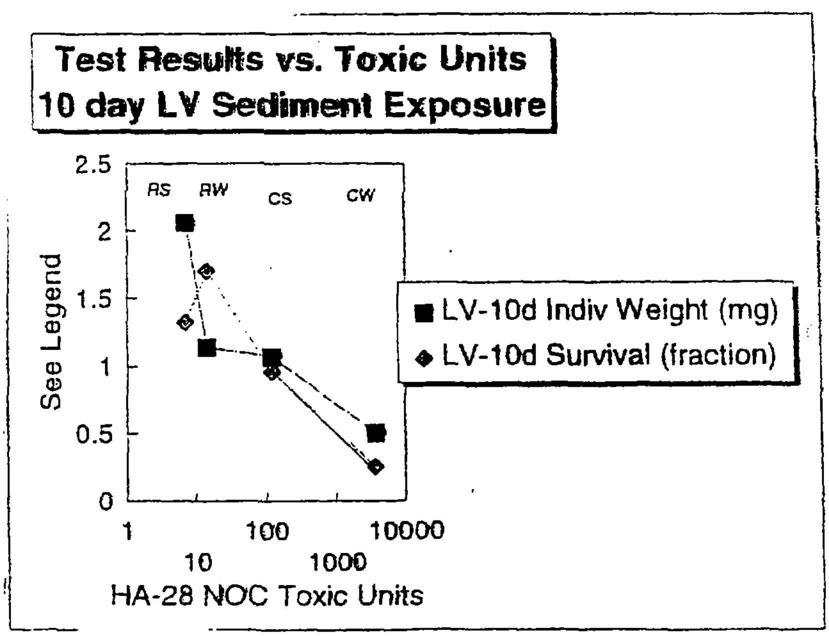


Toxicity Testing

CT = Chironomus tentans
HA = Hyalella azteca
LV = Lumbriculus variegatus

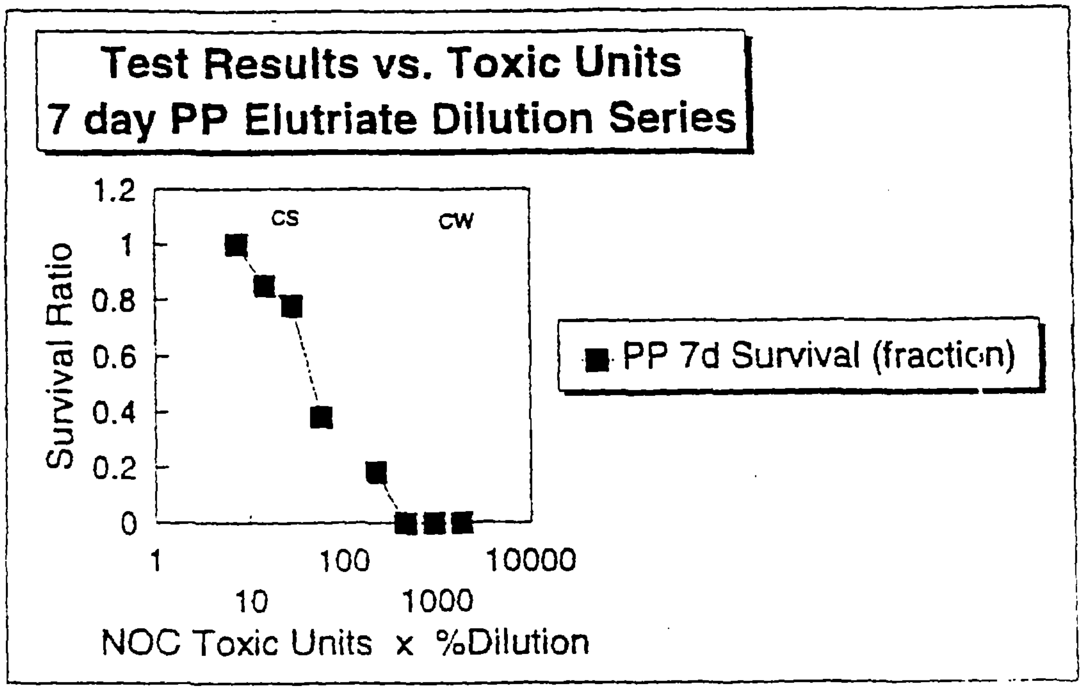
Ashland Lakefront Property Harbor Area Sediments

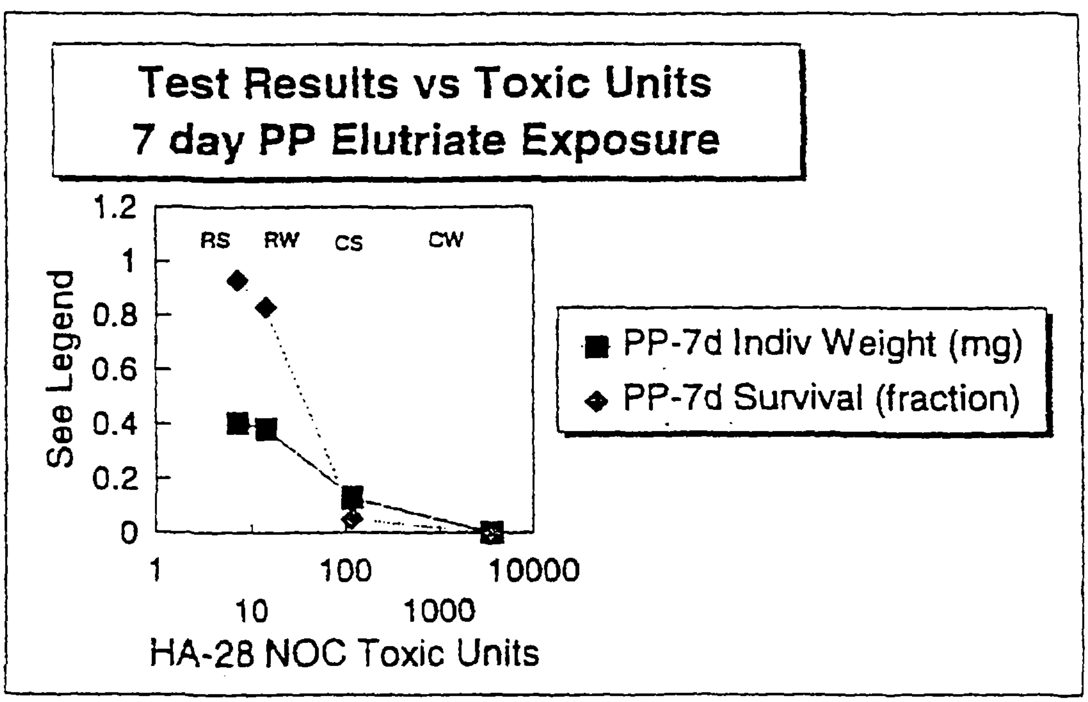


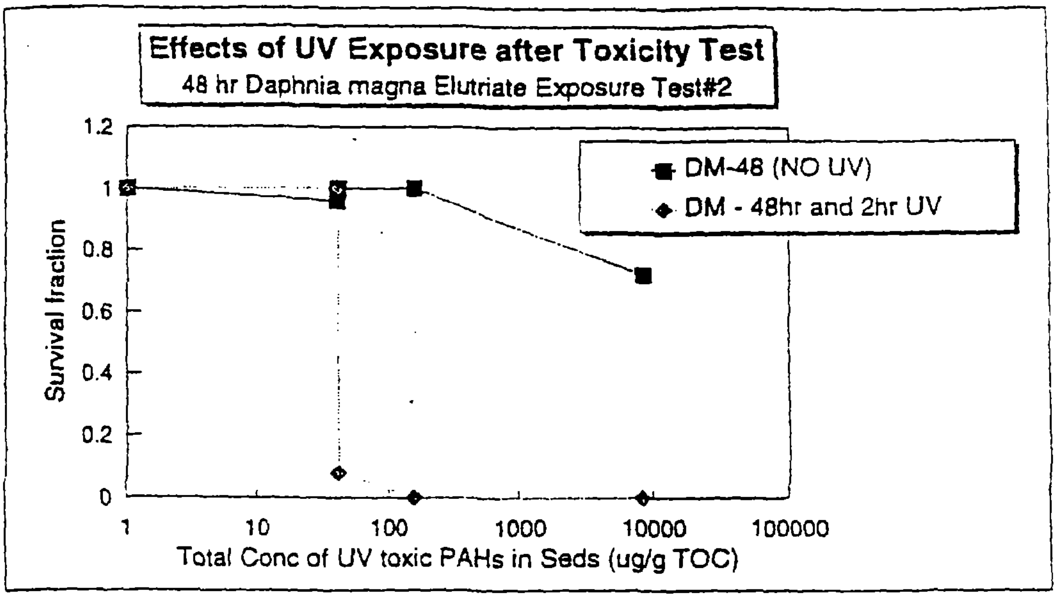


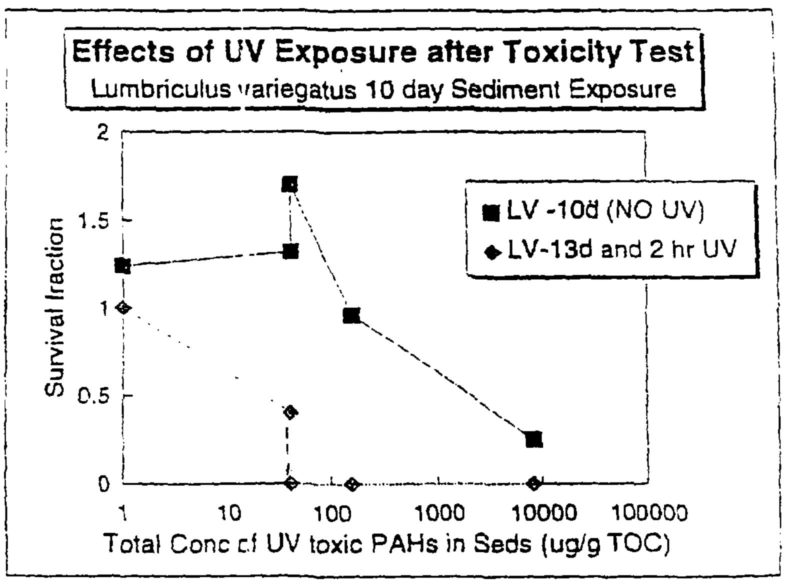
Toxicity Testing of Sediment Elutriates Using Fathead Minnows

Ashland Lakefront Property
Harbor Sediments





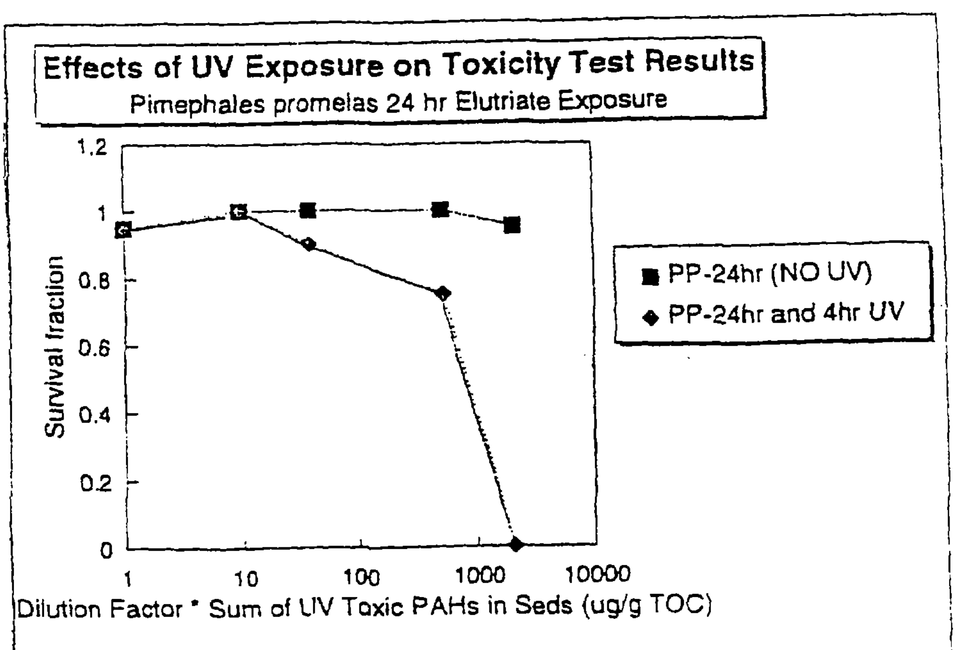




Toxicity Testing

Ultra Violet Light Exposures

Ashland Lakefront Property Harbor Area



able 1. Results of PAH Analysis Of Fish Tissue Collected 05/18/98 and 10/14/98 From Harbor Area Off the Ashland Lakefront Property

PAHs				Fish Tissue Concentration of PAHs (ug / kg) - Harbor Off Lakefront Property								
				9812	9810	9811	9813	98AS01	98AS02	9805	9809	98AS05
Low Mol. Wt.	No. Rings	Kow	Solubility mg/l	Fillet	Whole Fish	Fillet	Fillet	Fillet	Fillet	Whole Fish	Whole Fish	Fillet
Naphthalene	2	3.36	31.7	(19)1.	110		-35-2.	-34-	93	34	71	-38-
Acenaphthylene	3	4.07	3.93	(21)								
Acenaphthene	3	3.92	3.47	(17)	200	-17-	-53-		120		83	-48-
Anthracene	3	4.54	0.073	(7.1)	-21-				-7.6-			
Fluorene	3	4.38	1.98	(58)	73							
Phenanthrene	3	4.57	1.29	(19)	79		-17-	-17-	-47-			
High Mol. Wt. ↓	Total LMW Concen.-->			0	483	17	105	51	318.6		154	86
Fluoranthene	4	5.22	0.26	(29)								
Pyrene	4	5.18	0.135	(12)								
Chrysene	4	5.79	0.014	(7.4)								
Benzol(a)anthracene	4	5.91	0.014	(19)								
Benzol(a)pyrene	5	6.42	0.0038	(23)								
Benzol(b)fluoranthene	5	6.60	0.0012	(32)								
Benzol(k)fluoranthene	5	6.85	0.0006	(21)								
Dibenzo(a,h)anthracene	5	6.50	0.0005	(8)								
Indeno(1,2,3-c,d)pyrene	6	7.66	0.062	(34)								
Benzol(g,h,i)perylene	6	7.05	0.0003	(22)								
% Lipids	-----		-----	2.8	7.5	1.3	1.3	3.7	10	3.3	0.8	2.9

Value in parenthesis is the reported level of detection (LOD) for the compound. The LODs for sample 9810 are the same for the other samples that have no lues placed in the columns under that sample.
A value with a hypen on either side, e.g. -19-, indicates that the value reported is between the LOD and LOQ.
See next page for species analyzed and characteristics.

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Fish species and characteristics

Fish Where PAHs Detected In Tissue (% lipids given in the table above)
9810 - Shorthead redhorse, 18.4 in., 1.08 kg, whole fish
9811 - Smallmouth bass, 9.8 in., 022 kg, skin on fillet
9813 - Northern Pike - 22.5 in., 1.21, skin on fillet
98AS01 - Brown Trout, 21.25 in., 1.69 kg, skin on fillet
98AS02 - Rainbow Trout, 20.5 in., 2.02 kg, skin on fillet
98AS05 - White sucker, 17.5 in., 0.86 kg, skin on fillet
9805 - Pumpkinseed, 5.0 in. 0.04 kg, whole fish
9809 - Shorthead redhorse, 18.2 kg, whole fish

Fish Were PAHs Not Detected In Tissue
98AS04 - Largemouth Bass, 10.0 in., 28 kg, skin on fillet, 0.8% lipids
98AS03 - White Sucker, 17.75 in., 0.91 kg, skin on fillet, 1.0% lipids
9812 - Walleye, 17.8 in., 0.77 kg, skin on fillet, 2.8% lipids (listed in table above for indication of LODs
9801 - Rock Bass, 6 in, 0.07 kg, skin on fillet, 0.7% lipids
9802 - Rock Bass, 5.9 in., 0.08 kg, skin on fillet, 1.0% lipids
9803 - Rock Bass, 7.8 in., 0.17 kg, skin on fillet, 0.9% lipids
9804 - Rock Bass, 9.8 in., 0.36 kg, skin on fillet, 0.7% lipids
9806 - White Sucker, 15.9 in., 0.69 kg, skin on fillet, 2.4%
9807 - White Sucker, 16.5 in., 0.68 kg, skin on fillet, 1.7%
9808 - White Sucker, 18.2 in., 1.02 kg, skin on fillet, 2.5%

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PAH Sediment Concentrations and Related Toxicity Units At the Study Sites

Type of Bottom Substrate Sampled	Total PAHs ug / kg (dry wt.)	Sum of UV Toxic PAHs[1.] Organic Carbon Normalized ug PAH/g TOC	Total Toxic Units[2.]	
			Based on dry wt.	Organic Carbon Normalized
Reference Sand	424	40.9	1	7
Contaminated Sand	1,459	156	7	119
Reference Wood	6,543	41.1	31	14
Contaminated Wood	370,200	8,294	1,711	3,728

1. *PAHs identified to be associated with phototoxic effects based on the literature - anthracene, benzo(a)pyrene, dibenzo(a)anthracene, pyrene, benzo(k)fluoranthene, and benzo(g,h,i)perylene.*

2. *Based on Ingersoll HA 28 d ERM values or Effect Range - Median Values. ERM values associated with frequent or probable adverse biological effects.*

$$\frac{\text{Sediment Concentration of the PAH Compound}}{\text{HA 28 d ERM Concentration for the PAH Compound}} = \text{Toxic Units}$$

Toxic Units for Individual PAHs at a site are summed To Derive a Total Toxic Unit Value for the sample site.

CORRESPONDENCE/MEMORANDUM ————————————— **State of Wisconsin**

DATE: April 16, 1999 FILE REF: 3200

TO: Jim Hosch - NOR/Superior

FROM: Tom Janisch - WT/2

SUBJECT: Bureau of Watershed Management Recommendations For a Sediment Cleanup Goal For Total Polycyclic Aromatic Hydrocarbon (TPAHs) Compounds Based On the Ecological Risk Assessment Performed On the Sediments Offshore of the Ashland Lakefront Property

Considerations In Deriving Sediment Quality Objectives For TPAHs To Protect the Aquatic Ecosystem

The focus for development of sediment quality objectives to drive the cleanup of the contaminated offshore sediments is based on the information that a likely contributing source was releases of wastes associated with the former Manufactured Gas Plant (MGP) operation. Information on the contaminants from this likely source and possible types of wastes generated yields information on the possible ecotoxic properties of the wastes. The coal tars and other MGP wastes are complex wastes which can contain a number of toxic contaminants including a large number of organic compounds. Many of the contaminants in the wastes are potentially toxic to aquatic organisms. Aquatic-dependent wildlife that may utilize the nearshore impacted area including shorebirds, waterfowl, colonial nesting birds (e.g. terns), near-shore nesters (e.g. tree swallows), and raptors may be impacted from dietary exposure to the contaminants or through reduction in availability of food organisms.

The recommendation for a sediment quality objective will focus on the PAHs as a group based on the fact that: 1) PAHs are a primary component of the site sediment contamination which likely originated from the MGP waste source, 2) standardized analytical methodology exists for these compounds, 3) a number of sets of existing sediment quality guidelines contain PAH effect-based values principally from toxicity testing studies and studies involving concurrent sampling of sediment PAH concentrations and benthic organisms, 4) the extensive literature base that documents the effects of exposure to PAHs by aquatic organisms, and 5) the site specific studies conducted on the offshore Lakefront sediments in Ashland demonstrated effect-based associations with increasing PAH concentrations in the sediments, in the sediment elutriate water, and ~~in the~~ in the elutriate water exposed to representative portions of ultra-violet light from the solar spectrum.

In focusing on the parent, unsubstituted PAH compounds to drive the cleanup of the site, it is assumed that any other toxic components present are co-located (and may be contributing to the toxicity) in the sediments with the PAHs and will be addressed in the remedy directed at reducing or eliminating toxic exposures to aquatic organisms from the PAHs. It is recommended that the confirmation sampling be conducted if a remedial action is chosen involving dredging of the contaminated sediments. The confirmation sampling should include sediment testing for mutagenic properties of the exposed surface and underlying sediments and standard toxicity bioassays as well as chemical testing for PAH concentrations to ensure all toxic properties of the sediments due to other than PAHs have been addressed.

The recommended sediment quality objective for TPAHs is based on an additive toxic-units model approach rather than chemical concentration values for all the individual PAHs of concern. The assumption of

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additivity of the individual PAH compounds is supported by several investigations of the interactions of PAH compounds in aquatic organisms. As discussed in the Ecological Risk Assessment (SEH, 1998) for the contaminated sediments associated with the Ashland Lakefront Property, the basis for the toxic unit (TU) approach upon which the sediment quality objectives are derived are the Effect Range - Median (ER-M) values from Ingersoll et al. (1996). The sediment effect dry weight and organic carbon normalized values for the individual PAHs, the grouped low and high molecular weight PAHs, and total PAHs from Ingersoll et al. are shown in Table 1. The derivation of the TU values based on the PAH concentrations at a sample site is shown at the bottom of the table.

In deriving and applying of the developed sediment quality objectives for TPAHs, several considerations should be kept in mind:

1) A non-sediment matrix involving the overlying wood waste is also contaminated. The intent is to apply the sediment quality objectives to the offshore mineral sediments as well as the overlying wood wastes.

2) The toxicity testing component of the ecological risk assessment for the site from which the sediment quality objectives (SQOs) are derived largely involved acute exposures of 10-days duration. Since this does not provide a measure of the risks of long term exposure of aquatic organisms to PAH mixtures and resulting chronic and subchronic effects, the resulting SQOs based on only acute effects may be under protective of the aquatic ecosystem.

3) The Ingersoll et al. ER-M values that serve as the basis of the TU concept for the SQOs for mixtures of PAHs are by definition intended to represent the concentration of a PAHs in sediment above which adverse effects to the amphipod *Hyalella azteca* occurs frequently and are probable. Depending on the particular benthic species, effects may occur at lower levels and more sensitive species may not be protected when exposed to a mixture of PAHs. Use of the ER-M values in the TU model may also be underprotective of the aquatic ecosystem. Use of the ER-M values as well as the results from the acute toxicity testing adds to the degree of certainty in predicting the effects of exposures to PAHs by aquatic organisms but does not fully address long term exposure effects or exposure by sensitive organisms to lower levels of contamination.

4) The recommended TPAH SQC is based on the data set available from the site studies with consideration of applicable studies in the literature. Data from additional studies and further development and verification of the U.S. EPA EQP-QSAR Narcosis model to predict toxicity of mixtures of PAHs may change the present recommended SQO for TPAH.

5) The recommended SQO for TPAH are scientifically-based and established to protect the components of the aquatic ecosystem. The SQO do not consider social, technical, or economic factors that may also need to be considered by risk managers for the site in making remediation decisions.

Recommended Sediment Quality Objective TPAH Values To Protect the Aquatic Ecosystem

Along with the above considerations, Table 2 summarizes the results from the toxicity testing and benthic community studies performed on the Lakefront sediments (Tables 15 and 16 of the ERA) that were reviewed in developing the recommended SQO TPAH values. Also reviewed and considered were the toxicity testing results involving the elutriates of the Table 2 sediments which included ultra-violet light exposures. Given the available data set and the considerations of the ERA as to what amount of change constitutes a significant ecological impact, the following are the interpolated SQO recommendations for the TPAHs in the sediments offshore of the Lakefront Property sediments expressed in various interchangeable units in order to prevent or limit ecological impacts:

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TPAH SQO Expressed as Toxic Units (TUs) Usiing Ingersoll ER-M Values as a point of reference		TPAH SQO Expressed as Sediment Concentration	
Organic Carbon Normalized TUs	Dry Weight Normalized TUs	Organic Carbon Normalized Basis (Assumes ave TOC of 3.5 %)	Bulk Sediment Dry Weight Basis
10	7	80 - 120 ug TPAH / g TOC	2,500 - 3,000 ug TPAH / kg sediment

If you have any comments or questions on the above SQOs or development process, please call me.

cc: Lee Liebenstein - WT/2

Table 1. Sediment Effect Concentrations For PAHs From Ingersoll[1] Used In the Ashland Harbor Sediment Ecological Risk Assessment To Calculate Toxic Units.

PAH Compound From Coal Tar Residual Source	Effect Range - Median (ERM)[1] (From 28 d Toxicity Testing Using *Hyalella azteca)*	
	Dry Weight ug PAH / kg Sed.	Normalized To TOC ug PAH / g TOC
Acenaphthene	-----	-----
Acenaphthylene	-----	1.0
Anthracene	140	4.55
Benzo (a) Anthracene	300	14.09
Benzo (a) Pyrene	465	11.22
Benzo (b) Fluoranthene	71	2.39
Benzo (k) Flouranthene	71	2.39
Benzo (ghi) Perylene	275	10.62
Chrysene	500	16.76
Dibenzo (a,h) Anthracene	15	1.13
Fluoranthene	175	7.62
Fluorene	140	3.29
Indeno (1,2,3-cd) Pyrene	250	9.05
Naphthtalene	98	3.64
Phenanthrene	345	13.85
Pyrene	348	18.3
Total PAHs	2,200	105.2
LMW PAHs	653	31.1
HMW PAHs	1,746	96.2

1. Ingersoll, C.G. et al. 1996. Calculation and Evaluation of Sediment Effect Concentrations For the Amphipod *Hyalella Azteca* and the Midge *Chironomus Riparius*. EPA 905-R96-008. ERM value is associated with probable or frequent adverse biological effects.

$$\frac{\text{Sediment Concentration of the PAH Compound}}{\text{HA 28 d ERM Concentration for the PAH Compound}} = \text{Toxic Units}$$

Toxic Units for Individual PAHs at a Site are Summed To Derive a Total Toxic Unit Value for the sample site.

Table 4 . Use of the Swartz et al. (1995) Additive Toxicity Index Approach To Calculate Summed LC50 and EC25 Toxicity Units For the Lakefront Property Sediments - Ashland Harbor

Sample Grid Coordinates			Sample Depth	Estimated TPAH Pore Water Concentration ug / L	TPAH Sediment Concentration mg / kg	Σ LC50 Toxicity Units (TUs) Freshwater Application	Σ EC25 Toxicity Units (TUs) Freshwater Application
Site Order	North	East					
1	2600	2100	0 - 6 in.	0.21	0.40	0.011	**0.10**
2	2500	1800	0 - 4 ft.	20.8	6.36	0.03	**0.40**
3 RS	2800	2500	0 - 6 in.	0.096	0.42	0.07	**0.43**
4 CS	2550	1450	0 - 6 in.	6.92	1.46	0.08	**0.60**
5	2600	1800	0 - 4 ft.	71.66	4.74	0.05	**0.82**
Remediation of areas of the off-shore sediments would be required where the sum of (Σ) EC25 Toxicity Units (TUs) based on pore water concentrations of the individual PAHs is greater than 1.0.							
6	2400	2100	0 - 4 ft.	19.0	21.12	0.44	**3.40**
7	2800	1900	0 - 4 ft.	152.0	25.35	0.47	**4.98**
8	2100	900	0 - 6 in.	8.97	21.9	0.66	**5.36**
9	2500	1800	0 - 6 in.	7.02	6.34	2.03	**5.97**
10 RW	2600	2100	0 - 6 in.	12.25	6.54	1.48	**7.32**
11	2600	1400	0 - 4 ft.	563.9	217.18	1.77	**17.63**
12	2600	1900	0 - 4 ft.	695	95.38	1.55	**17.70**
13	2800	1400	0 - 6 in.	46.40	38.28	4.61	**19.26**
14	2800	2300	0 - 4 ft.	732.22	127.51	2.54	**26.14**
15	2500	1700	0 - 4 ft.	1619.21	220.11	3.73	**40.89**
16	2400	1600	0 - 4 ft.	1609.34	223.09	3.79	**42.17**
17	2300	1400	0 - 4 ft.	1823.84	242.48	4.06	**45.41**
18	2500	1400	0 - 4 ft.	1506.03	221.41	4.77	**48.48**
19	2300	1700	0 - 4 ft.	2698.95	285.01	4.25	**51.49**
						[illegible]	[illegible]